3.6 GEOLOGY AND SOILS

This section describes the existing geologic and soil environment in the vicinity of the proposed project. Discussions of geology and soils that apply to all three proposed corridors are followed, respectively, by information specific to the Western, Central, and Crossover Corridors.

3.6.1 Geology

The proposed project area is located within the Basin and Range Physiographic Province that is characterized by alternating mountain ranges and broad valleys, most of which were formed by block faulting during the last part of the Cenozoic Era, 5 to 15 million years ago (NRCS 2001).

Elevations in the vicinity of the three proposed corridors range from 2,675 ft (815 m) above mean sea level (AMSL) at the South Substation to the high point in the Coronado National Forest of 6,244 ft (1,903 m) AMSL at the Atascosa Fire Lookout. The elevation at the U.S.-Mexico border is 4,085 ft (1,245 m) AMSL. Ground slope within the Tumacacori Ecosystem Management Area (EMA) varies from nearly flat to over 40 percent, with over half the land at 15 to 40 percent slope, and steeper slopes within the Tumacacori and Atascosa Mountains (USFS 2001b).

Several geologic units are present along the three proposed corridors, such as unconsolidated sediments (surficial alluvium deposited by running water), sedimentary rock, and volcanics (Figure 3.6–1). The unconsolidated sediments include young alluvium and older surficial deposits. The young alluvium consists of sediments carried from the mountains and deposited in present-day rivers and stream channels, floodplains, and playas. The older surficial deposits consist of alluvial and aeolian (wind-deposited) deposits found in present-day valleys and piedmonts (bases of mountains).

Geologic Resources. As is common in many areas of Arizona, the Santa Cruz Valley contains abundant geologic resources, including copper, molybdenum, silver, and gold, that are mined along the common northern segments of the three proposed corridors.

Sand and gravel mining operations do not occur within the three proposed corridors, and there are no significant coal or oil and gas resources in the immediate area. Inactive mine tailing areas are located adjacent to the common northern segments of the three proposed corridor west of Sahuarita, in Township 17 South, Range 13 East.

Geologic Hazards. The geologic hazards that could affect the project include faults and seismic activity, and ground failures such as slumping, landslides, debris flows, and subsidence causing ground fissures.

Faults and Seismic Hazards. In order to assess earthquake hazards, historical earthquakes are described and faults along which movement has occurred in the past 2 million years (the Quaternary Period) are mapped and characterized. The historical record of earthquakes in Arizona dates to about 1776, but records are sparse prior to the late 1800s. The following discussion of earthquake hazard is primarily summarized from an Arizona Geological Survey publication, *Arizona Geology* (Arizona 2000).

Since 1850, over 20 earthquakes with magnitudes greater than 5 on the Richter Scale have occurred in or near Arizona. A table of the Richter scale and its description is shown in Table 3.6–1. Most earthquakes have occurred in northern Arizona and in California, adjacent to the southwest corner of Arizona. The largest earthquake recorded in the region was the magnitude 7.4 (on the Richter Scale) Sonoran earthquake of 1887. It was centered about 125 mi (205 km) southeast of Sahuarita, and caused 51 deaths in Sonora and extensive property damage throughout southeastern Arizona. The fault that generated the 1887 Sonoran earthquake probably had not caused a similar earthquake for at least 100,000 years (Arizona 2000).

Table 3.6–1. Richter Scale.

Magnitude	Descriptor
Less than 3.0	Very minor-generally not felt
3-3.9	Minor-generally felt, no damage
4-4.9	Light-felt widely, slight damage near epicenter
5-5.9	Moderate-damage to poorly constructed buildings
6-6.9	Strong-can be destructive in areas up to approximately 100 km across where people live
7-7.9	Major-can cause serious damage over larger areas
8 and higher	Great-can cause serious damage in areas several hundred km across

Source: Richter 2003, USGS 2003.

Potentially active faults that could generate magnitude 6.5 to 7.2 earthquakes are scattered throughout southeastern and central Arizona, including much of the Phoenix and Tucson areas. Earthquakes of this magnitude are considered to be destructive to major ones. All of the potentially active faults in the Phoenix and Tucson areas have low slip rates, long intervals between ruptures, and have had little historic activity. Because of this, the Arizona Geological Survey places these areas in the low to moderate hazard category.

Slumping, Landslides, and Debris Flows. Almost any steep or rugged terrain is susceptible to slope failure under certain conditions. Flash floods, however, can occur in the numerous narrow washes that cross the valley floor of the proposed project area.

Subsidence. Extensive and long-term groundwater withdrawal can in some areas cause ground subsidence. Over time, this can lead to ground fissures given the right geologic conditions. This geologic hazard is a concern in the Tucson area and areas north of Tucson, as substantial ground subsidence with resultant fissures has occurred in these areas of Arizona. Subsidence hazards have not been documented along the three proposed corridors, and are therefore not expected.

3.6.1.1 *Western Corridor*

As part of the analysis of roads required by the U.S. Department of Agriculture Forest Service (USFS), Terracon conducted a geotechnical evaluation of the proposed project area on the Coronado National Forest (Terracon 2002). Relatively intact bedrock is near to or exposed at the ground surface along the majority of the Western Corridor on the western side of the Tumacacori Mountains, as shown by the areas of tertiary conglomerate and sandstone in Figure 3.6–2 on national forest land (Terracon 2002). The photograph in Figure 3.6–3 shows exposed bedrock along the Western Corridor. The bedrock would be suitable for supporting poles on a rock bolted base, in which small holes are drilled into the bedrock and the tower is attached with large bolt, as described in Section 4.6, Geology and Soils.

Areas of the Western Corridor that are relatively flat (much of the northern half of the corridor) may be considered too flat to be affected by mass movements such as slumping, landslides, and debris flows. The terrain along the Western Corridor has relatively mild slopes, except where it crosses occasional drainages and steep mountain slopes (Terracon 2002). The mountainous areas of the Western Corridor, primarily located in the Coronado National Forest, can be considered areas where mass movements could occur. The U.S. Geological Survey (USGS) has mapped much of the Coronado National Forest as general areas susceptible to debris flows, although none have been documented in the project area (USGS 1999).

Castle Rock is a prominent topographical feature at the edge of the Western study corridor south of Peña Blanca Lake (as shown in Figure 3.2–2). TEP's preliminary siting of the 125-ft (38-m) right-of-way (ROW) avoids this rocky outcrop.

Figure 3.6–3. Exposed Bedrock Along the Western Corridor.

3.6.1.2 *Central Corridor*

A majority of the Central Corridor near and on the Tumacacori EMA has exposed soil at the surface rather than bedrock, as depicted by areas of Quaternary alluvium in Figure 3.6–1, and as shown in Figure 3.6–4. The foundations for towers along the Central Corridor in these exposed soil areas would most likely require embedment poles, as described in Section 4.6, Geology. The terrain along the Central Corridor is generally defined by a series of hills separated by washes (Terracon 2002).

3.6.1.3 *Crossover Corridor*

The discussion of geology for the Western and Central Corridors also applies to the Crossover Corridor in segments where these corridors overlap. Where the Crossover Corridor passes through Peck Canyon for approximately 7 mi (11 km), the majority of the land has bedrock exposed at the surface. The terrain along Peck Canyon is rough and jagged, with steeply sloping canyon walls and a narrow winding canyon bottom (Terracon 2002).

3.6.2 Soils

This section describes the existing soil environment in the vicinity of the proposed project. Depending on the type of soil present in each proposed corridor, foundations used in the area would differ as described in Section 4.6, Geology and Soils.

Figure 3.6–4. Exposed Soil Along the Central Corridor.

Soil Map Units. The three proposed corridors would cross five soil associations, as mapped by the Natural Resources Conservation Service (NRCS) and shown in Figure 3.6–5. None of the soils identified have any characteristics that would present any obstruction to standard construction techniques. Brief summaries of the soil associations in the corridors are provided below (USDA 1979).

Comoro-Pima Association. This soil association consists of well-drained sandy and clay loams (an easily crumbled mixture of clay and sand) to a depth of 60 in (152 cm) or more. These soils are on floodplains with slopes ranging from 1 to 3 percent and alluvial fans (fan-shaped deposits that are dropped by a stream) with slopes from 1 to 10 percent. The permeability (quality of soil that enables water or air to move through it) is moderate to rapid. The soil erosion hazard is generally slight, but soils in narrow drainages can be susceptible to gully erosion. Soils in floodplains can be subject to seasonal flooding.

Continental-Sonoita Association. This soil association consists of well-drained gravelly sandy loams to a depth of 60 in (152 cm) or more. Continental soils are typically found on older alluvial fans and terraces with slopes ranging 1 to 15 percent. Sonoita soils are found on reworked fan remnants with slopes typically ranging from 1 to 20 percent; although some short terrace breaks (raised embankment with a leveled top) have slopes as great as 45 percent. Permeability is moderately slow to moderate. The erosion hazard is generally slight in the different series comprising this association. The exception is the gravelly loams of the Rillino Series. These soils occur on the ends and sides of long narrow ridge remnants of dissected alluvial fans where runoff is rapid, and the erosion potential is high.

Bernardino-White House-Hathaway Association. This soil association consists of deep gravelly clay loams, gravelly sandy loams, gravelly loams, or clays to a depth of 60 in (152 cm) or more. This soil association is typically found on fans or piedmont plains (formed at the base of mountains) with slopes ranging from 0 to 45 percent. The erosion hazard is generally slight to moderate, except in two series that occur on steep slopes on either long, narrow sides of ridges or on strongly dissected upper old alluvial fans.

Caralampi-White House-Hathaway Association. This soil association consists of deep gravelly loams or gravelly sandy loams to a depth of 60 in (152 cm) or more. This soil association is typically found on dissected fans and piedmonts with slopes ranging from 10 to 60 percent. Permeability is moderate or slow. The erosion hazard is slight to high, and is primarily dependent upon slope, with the steeper slopes and vertical scarps (a line of cliffs produced by faulting or erosion) posing a higher erosion potential.

Lampshire-Chiricahua-Graham Association. This soil association consists of very cobbly (coarse) loams, very cobbly clay loams, or cobbly sandy loams with shallow to very shallow depths. Lampshire soils are 4 to 20 in (10 to 51 cm) deep and occur on mountains. Chiricahua are 20 in (50 cm) deep and are found on foothills and low mountains. Graham Soils are 10 to 20 in (25 to 51 cm) deep and on lower parts of mountains. Slopes range from 0 to 60 percent. Permeability above bedrock (solid rock beneath loose surface material) is moderate or slow. The erosion hazard is primarily slight to moderate, but is high on some steep slopes in the Atascosa and Tumacacori Mountains.

Prime Farmland. The NRCS has designated certain soil types as "prime farmland" subject to protection under the *Farmland Protection Policy Act.* Soils that are classified as prime farmland derive their value from their general advantage as cropland due to soil and water conditions. These soils are best suited for producing food, feed, fiber, forage, and crops. They have favorable growing seasons and receive sufficient quantities of moisture to produce yields on average of 8 out of every 10 years. The only soil types found in the corridors that are classified as prime farmland are the Comoro soil series (0 to 5 percent slope only, and referred to as Comoro soils in this document) and the Pima soil series. These soils are found within the Continental-Sonoita and Comoro-Pima soil associations, and are considered prime farmland only when irrigated.

Coronado National Forest Soil Classifications. USFS has classified the soil condition of the Tumacacori EMA, based on the vegetation, slope, and soil type combination, or on the watershed condition rating where the former were unavailable. Satisfactory soil condition indicates the current soil loss is below the tolerance level, and unsatisfactory soil condition indicates the current soil loss is above the tolerance level.

3.6.2.1 *Western Corridor*

The Western Corridor begins on the Comoro-Pima soil association and crosses the Bernardino-White House-Hathaway, Continental-Sonoita, and Lampshire-Chiricahua-Graham associations before separating from the Central Corridor. It continues on the Lampshire-Chiricahua-Graham association and crosses areas of the Comoro-Pima and Continental-Sonoita associations before entering the Coronado National Forest.

On the Coronado National Forest, the Western Corridor crosses primarily the Lampshire-Chiricahua-Graham association, and crosses the Caralampi-White House-Hathaway association for the remainder of the route to Nogales. The Western Corridor passes through unsatisfactory soil conditions upon entering the Tumacacori EMA from the north, then passes through satisfactory soil conditions as it turns east at Ruby Road, and exits the Tumacacori EMA near Nogales again in unsatisfactory soil conditions (USFS 2001b).

In Santa Cruz County, the Western Corridor would cross approximately 1,900 linear ft (580 m) of prime farmland soils located in the far northwest corner of the county. These soils are Comoro soils and are grouped within the Continental-Sonoita soil association. These soils are found in the area of the Sopori and Batamote Washes and are considered prime farmland only when irrigated. Some of the area of Sopori and Batamote Washes are irrigated and farmed.

The NRCS soil survey for the project area within Pima County is out of print and not publicly available. However, staff from the local NRCS office indicated that there are little, if any, prime farmland soils (when irrigated) in the project area of Pima County (NRCS 2003).

3.6.2.2 *Central Corridor*

After separating from the Western Corridor, the Central Corridor continues on the Lampshire-Chiricahua-Graham association, crosses a small area of the Comoro-Pima association, and continues on the Continental-Sonoita association to the Coronado National Forest boundary, as shown in Figure 3.6–4. The soils in the Central Corridor primarily consist of gravelly sands with a high percentage of cobbles and boulders (Terracon 2002).

On the Coronado National Forest, the Central Corridor crosses primarily the Caralampi-White House-Hathaway association, with a short section of the Lampshire-Chiricahua-Graham association just north of the crossing of Ruby Road. The Central Corridor passes almost entirely through unsatisfactory soil conditions, as described in Section 3.6.2.1, within the Tumacacori EMA (USFS 2001b).

In Santa Cruz County, the Central Corridor would cross approximately 5,600 linear ft (1,700 m) of prime farmland soils located near Amado and Tubac. Near Tubac, approximately 1,000 linear ft (305 m) of prime farmland soils would be crossed in the vicinity of Puerto Canyon and Tubac Creek. These soils are the Comoro soils and are grouped within the Continental-Sonoita soil association. In the Amado area, approximately 4,600 linear ft (1,400 m) of prime farmland soils would be crossed in the area of the Toros, Sopori, Diablo, and Las Chivas Washes. These soils are Comoro soils (grouped within the Continental-Sonoita and Comoro-Pima soil associations), and Pima soils (within the Comoro-Pima association). All prime farmland soils within the project area are considered as such only when irrigated.

Specific locations of prime farmland soils in the corridors within Pima County have not been determined.

3.6.2.3 *Crossover Corridor*

The portion of the Crossover Corridor that is not common to one of the other corridors crosses primarily the Lampshire-Chiricahua-Graham association, plus a small area of the Caralampi-White House-Hathaway association. The Crossover Corridor passes almost entirely through unsatisfactory soil conditions, as described in Section 3.6.2.1, except for the east-west crossing through Peck Canyon, where the soil conditions are satisfactory (USFS 2001b).

There are no prime farmland soils located within the Crossover Corridor, except for where it is common with the Western Corridor in the northwest corner of Santa Cruz County, as described in Section 3.6.2.1.